VOLUME XXXII NUMBER 5 WHOLE NUMBER 274

THE JOURNAL

OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR, C. A. CHANT ASSISTANT EDITOR, F. S. HOGG
David Dunlap Observatory
Richmond Hill P.O., Ont.

ASSOCIATE EDITORS

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Dominion Astronomer
Ottawa

W. E. HARPER
Director of the Dominion Astrophysical Observatory
Victoria, B.C.

J. PATTERSON
Controller of the Meteorological Service of Canada, Toronto

PUBLISHED MONTHLY
(*Ten numbers per year*)

May-June, 1938

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

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TRANSATLANTIC AVIATION AND METEOROLOGY*

BY P. D. MACTAGGART-COWAN

THE first trans-atlantic flights are history. Most people remember the flight of Alcock and Brown on June 14th 1919, when they flew their Vickers Vimy Aircraft the 1890 miles between St. John's, Newfoundland, and Clifden, County Galway, Ireland, in 16¼ hours, to make the first non-stop Atlantic crossing, and the flight of Lindbergh on May 20-21, 1927, when he crossed from New York to Paris—a distance of 3,620 miles in 33 hours, down through a long list to the flights of Merrill and Richman, Mrs. Markham, and Mollison in 1936. But few people can know the vast amount of preparation and of study, and the detailed organization and effort that is turning stunt flights into a commercial proposition.

In this paper will be given a brief sketch of the general organization, a more detailed account of the problems facing the meteorological offices in providing a weather service, and the organization necessary to supply this information to the aircraft, with special reference to the work of the Botwood, Newfoundland, office of the Meteorological Service of Canada.

I. ROUTES AND BASES

The complete trans-north-atlantic air route is considered to extend from Southampton to New York. The first section is from

*From an address delivered at the meeting of the Toronto Center of the Royal Astronomical Society of Canada on December 7, 1937.

Southampton to Foynes, County Limerick, Ireland, the second from Foynes to Botwood, Newfoundland, where it branches. Imperial Airways take the route from Botwood up the St. Lawrence River to Montreal, Quebec, and from Montreal to Port Washington, New York; while Pan American aircraft fly the route from Botwood to Shediac, N.B., and thence Shediac to Port Washington.

Whichever route is followed, five countries are involved and it is greatly to the credit of all concerned in the establishing and operating of the various bases that there has been perfect harmony and co-operation between all branches of the Service during the first flying season which is of necessity the most trying.

But to return to the route and the bases:—the base at Hythe (Southampton) was already in existence as the terminus for all the Empire Air routes. Wireless and meteorological services were adequate and the base was fully equipped for maintenance and repair work so that it was the obvious Eastern terminus for the trans-north-atlantic air route.

The selection of the next base on the eastern side of the Atlantic was a more difficult problem. The requirements were to have it as far west as possible, in order to reduce the length of the ocean crossing to a minimum, consistent with good meteorological conditions. A site right on the west coast of Ireland was obviously impossible as the predominance of low cloud and poor visibility would make continued scheduled landings extremely difficult. Several sites were inspected and the one chosen, Foynes, is on the River Shannon far enough inland from the west coast of Ireland to escape the worst of the coastal climate. Mooring and refuelling facilities were installed. A wireless station equipped for short and medium wave reception and transmission and short and medium wave direction finding was constructed and staffed by the Irish government and a meteorological office, staffed by the British Air Ministry, established.

Simultaneously with this development the western terminus for the ocean section of the route was constructed at Botwood. Here again meteorological conditions played a large part in determining the site. The prevalence of fog on the Grand Banks and off the east coast of Newfoundland was well known but forty miles inland on the Bay of Exploits a site was found that is one of the finest natural sea bases in the British Empire. A large bay some two miles across, almost land locked, with a shore line rising

slowly to under three hundred feet is ideal; when combined with prevailing high ceilings and good visibility and an absence of sea fog it approaches perfection. Such are the merits of Botwood, and here the western terminus was temporarily constructed with facilities, equipment and personnel similar to that at Foynes. The wireless station at Botwood was staffed by the Air Ministry and

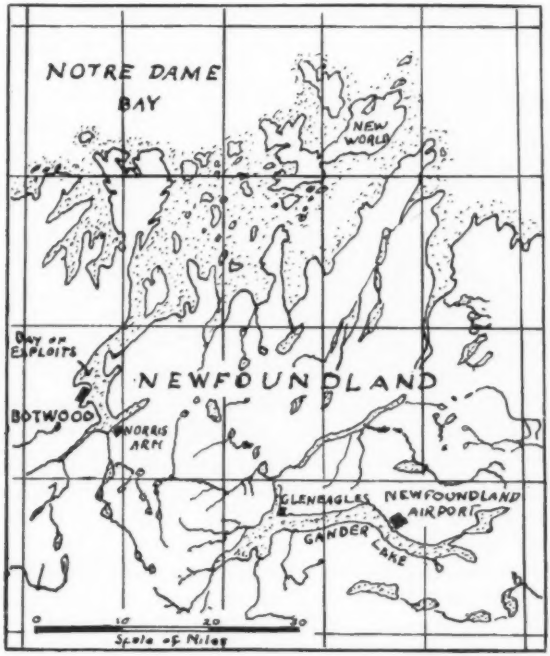


Fig. 1.—Map of Region of Botwood and Newfoundland Airports.

the meteorological office by the Meteorological Service of Canada. Offices and accommodation were supplied by the Newfoundland government.

At Montreal the sea base was established at Boucherville while wireless and meteorological services were supplied by the offices already in existence at St. Hubert Aerodrome.

Pan American Airways wished their Canadian base to lie as

near as possible on the direct route from Botwood to New York. Accordingly Shediac was chosen and mooring, refuelling and wireless equipment installed.

The western terminus, as in the case of the eastern, was already in existence at Port Washington on Long Island, N.Y. Here Pan American Airways had a satisfactory summer base with excellent facilities in all departments.

II. Preparation and Experiment

The provision of bases was only one phase of the preparation. As soon as the wireless equipment was installed, experiments were begun on short and medium wave point to point communication between the bases and suitable frequencies chosen for twenty-four hour services. The laborious calibrations of the direction-finding apparatus proceeded throughout the winter. The Meteorological Services of Great Britain and Canada were also preparing. Both meteorological offices had been making a special study of Atlantic weather for some some. These studies were intensified, staffs increased, and special researches in related problems undertaken. An officer of the British Meteorological Office was established on the S.S. Manchester Port and spent a year measuring the upper winds over the Atlantic and gathering data on cloud heights and types and similar elements of aeronautical importance.

By the spring of 1937 individual preparation was well advanced and it remained to weld the various sections together with a good organization.

At Botwood, wireless was the first unit to become established. The wireless station was built on the top of the first rise of land from the bay and was approximately a mile from the shore. A central building provided offices for the control and wireless officers and living quarters for the staff of fourteen operators. Five hundred yards to the west the transmitting building and masts were located, and at a similar distance to the east were the receiving building and masts, and the medium wave direction finding unit. The short wave direction finder was some four hundred yards to the north of the central building. There was no space to spare in any of these units but they were of solid construction in spite of their temporary nature.

By the time the meteorological staff arrived early in June, the

wireless staff had behind them several months of successful operation which proved invaluable in the rapid expansion that came later. Point to point communication had been established with Foynes, Port Washington and St. Hubert, and the British meteorological broadcasts from Rugby were received regularly.

But this failed to satisfy the ambitious programme of the meteorological staff. It had been tacitly assumed at the beginning that their needs could be met with an office somewhere in Botwood and copies of the International meteorological broadcasts amount-

Fig. 2.—Central Wireless Station, Botwood, Newfoundland.

ing to some 5,000 words per day. In the first week after the arrival of the meteorological staff it was found that the distance between their office and the wireless station, approximately two miles, was too far for efficient co-operation. This problem was soon solved by building offices in the Central Wireless building and installing wireless receivers for reception of broadcast messages and a key to the transmitter to work St. Hubert and Port Washington. Thus most of the meteorological information was received directly in the meteorological office. The data required by the office was found to be double that originally anticipated. The programme called for the preparation of four synoptic charts daily, based on observations from about four hundred land stations and ships, taken at $01^h\ 00^m$, $07^h\ 00^m$, $13^h\ 00^m$ and $18^h\ 00^m$ G.M.T. and covering a

region extending from the Pacific coast of North America to the eastern boundaries of Europe.

Most of the reports from stations in the United States were collected at Washington and broadcast twice daily from Arlington. For the other two periods the data was collected at Toronto, sent by teletype to St. Hubert, and relayed from there to Botwood. The reports from Canadian stations came four times daily through the Toronto-St. Hubert circuit. Weather reports from ships at sea were relayed from Arlington, Louisburg, St. John's, St. Hubert, Foynes, Port Washington and Rugby. The reports from European stations were received from Foynes and Rugby. In addition, selected American station reports were compiled at Botwood and relayed to Foynes. Weather reports were collected from Labrador stations and relayed to Toronto and Foynes.

Within a few weeks the wireless staff found themselves called upon to complete some fifty-six schedules daily with nine different stations, totalling between ten and twelve thousand words of code message.

An account of the troubles experienced in establishing these schedules, of the dawn effects in the early morning schedules with St. Hubert, of the northern lights and their effects on short wave communication, and with skip distances, would be out of place here; but without the untiring efforts and resourcefulness of the Botwood wireless staff and the full co-operation of all the stations involved, the meteorological office would have been seriously handicapped by lack of information.

Once established, the meteorological station at Botwood was very complete, having the full complement of instruments for a first-class weather reporting station, pilot balloon equipment for measuring the speed and direction of the upper winds, and the services of a seaplane for daily ascents to measure the vertical temperature and humidity distribution in the atmosphere and to take observations on heights of cloud tops, vertical visibility and icing conditions.

While these preparations were being carried out, the sea base began to take shape. Botwood itself is a small village on the west shore of the Bay of Exploits, straggling for several miles along the road that skirts the bay on this side. At the northern end of the village there is a small bay off which lies an island. The enclosed water is protected from all directions and here the sea base was constructed — a slipway built, mooring buoys placed and *Oscar*

anchored in the centre. *Oscar* was an aircraft refuelling barge built on generous proportions; complete with modern pumping equipment it proved to be an overwhelming success and is serving as a pattern for many others throughout the Empire air routes.

As a precautionary measure an emergency sea base was located at Gleneagles on Gander Lake, some thirty miles southeast of Botwood (see fig. 1). There auxiliary wireless, mooring and refuelling equipment was installed and a meteorological observer stationed so that if landing conditions were unfavourable at Botwood the aircraft could be brought down on the lake.

Fig. 3.—"The Folly", Staff House, Botwood, Newfoundland.

With an influx of fifteen men on the wireless and control staff, six on the meteorological staff, and two to handle the refuelling, the accommodation problem became acute. To meet this the Folly was built. The Folly is a staff house designed originally as a beautiful building to accommodate the crews of visiting aircraft and the officers in charge of the Botwood station. But plans failed to materialize and it degenerated into a rough frame structure which served only as living quarters.

III. The First Flight

By the last week in June everything was in readiness at Botwood and at the other bases.

The first test of the organization came on the 27th of June. On the 26th of June a 24 hour notice of departure was received from the Pan-American Airways flying Boat Clipper III for a flight from Port Washington to Botwood via Shediac, at $12^h\ 00^m$ G.M.T. June 27th. At $10^h\ 00^m$ G.M.T. the following morning a weather report for Botwood and a flight forecast for the route Shediac to Botwood was despatched to Port Washington. At $11^h\ 00^m$ and every hour thereafter on the hour, a Botwood weather report was sent to the aircraft. With the fourth of these a Botwood upper wind report was included. Fifteen minutes before the aircraft was due at Botwood, the report of landing conditions was despatched. The aircraft, in return, sent half-hourly position reports to every second of which was added a report of existing weather conditions. These were received at the bases and were checked step by step with the forecasts issued. Leaving Port Washington at $11^h\ 35^m$ G.M.T. the Clipper arrived in Botwood at $22^h\ 21^m$ after a stop of one and a half hours at Shediac.

After lying over a day at Botwood the Clipper III made the return flight to Port Washington on June 29th without incident.

This preliminary test was very successful. Wireless communication with the aircraft had been maintained throughout the flight without difficulty and the meteorological data had been successfully handled. As was to be expected a few minor weak points in the organization were brought to light and were quickly removed.

The complete test began on July 3rd when the Clipper III left Port Washington for her first Atlantic crossing. The Port Washington-Botwood flight was again satisfactorily completed. The following day flying schedules were commenced at St. Hubert, Botwood and Foynes. This further increased the number of schedules and required a general speeding up on all transmissions. It meant that every six hours the Foynes and Botwood meteorological offices exchanged appreciations of the weather over the North Atlantic and twelve-hour forecasts for their respective bases. For this the Atlantic Ocean was divided into two parts at longitude 30°W, Foynes sending their analysis of the weather to the east of this line and Botwood that to the west. This ensured that both bases were in agreement as to the analysis and that each was equipped with the most complete and detailed information that facilities and time allowed. With St. Hubert it meant a 24-hour wireless service to Botwood and a substantial increase in the daily

traffic. At $19^h\ 00^m$ G.M.T. July 4th a preliminary flight forecast was prepared by the Botwood office. This and all relevant data were discussed with the Captain of the Clipper and the Control Officer. Weather conditions appeared favourable and the forecast gave moderate tail winds at the 10,000 foot level and so departure was set for $21^h\ 00^m$ G.M.T. July 5th, on a great circle route at 10,000 feet, and the necessary notices were despatched to ships and coastal wireless stations.

Simultaneously the meteorological office at Foynes was supplying similar information to the Captain of the Caledonia. In this case the weather was not so encouraging. Large amounts of low cloud, rain and head winds were forecast—but such weather is to be expected in the Atlantic and the aircraft have a fuel capacity to cross against an average head wind of well over forty miles per hour. Departure of the Caledonia was set at $18^h\ 00^m$ G.M.T. July 5th for a rhumb line course at 1000-2000 feet.

Six hours before departure a revised forecast was issued based on the latest synoptic data. Four hours later a final flight forecast was issued together with a copy of the latest synoptic chart of the North Atlantic and Botwood upper winds and weather reports and a forecast from Foynes of the weather conditions expected there for the estimated time of the flight. Once the aircraft was air borne the meteorological and wireless ground-to-air organization was ostensibly a repetition of that tested on June 27th with, of course, exceptions arising out of increased distances, the length of the flight and the additional amount of meteorological data to be handled. At $02^h\ 00^m$ G.M.T. July 6th, the Clipper III passed out of the Botwood zone of control. Simultaneously the Caledonia moved in and the schedules continued to be maintained without a break. At $10^h\ 00^m$ G.M.T. the Caledonia arrived at Botwood. The Clipper was already water borne at Foynes and the first leg of the flight was over.

Wireless communication had been good. The meteorological data contained in the forecasts had proved reasonably accurate, especially the all important force and direction of the wind. The amount of cloud had been considerably under-estimated, but with the help of the weather reports received from the aircraft in flight, the cause of the error was found and a complete study of that and similar situations undertaken. The results showed that the final analysis derived from the interchange of appreciations between the

meteorological offices at Foynes and Botwood was a very fair representation of the weather over the Atlantic.

On July 8th the Caledonia left Botwood for Montreal. For this flight the wireless and weather stations in the Gulf and up the St Lawrence River co-operated to supply the aircraft with the latest weather reports and wireless bearings. The flight was concluded without incident as was the final leg of the route from Montreal to New York.

The successful completion of this and of the subsequent flights comprising fourteen crossings of the Atlantic has been referred to in so many publications that a reiteration here would be boring repetition. But the parts played by the Distress Organization and the Wireless and Meteorological Offices are worthy of recapitulation.

IV. The Distress Organization

The distress organization existed to handle any emergency that might occur during a flight. Under normal circumstances the duties of the distress officer were to collect and list the positions, course and speed of Atlantic shipping in the vicinity of the route, and to notify them of the proposed flight, the time of departure and route. The information collected was plotted on a large scale chart and a list of the ships and positions supplied the Captain of the aircraft before departure. During the flight, position reports were received from the aircraft every half-hour; these were immediately plotted on the chart so that the relative position of aircraft and shipping was known at all times. If communication between the base in control and the aircraft had failed, the ships in the vicinity would have been notified to stand by for possible distress calls and to report the position of the aircraft as soon as located. Occasion arose to try this out on the first flight of the Cambria and the result proved the efficiency of the system—within a very few minutes the desired position report was received and communication re-established.

V. The Wireless Organization

The wireless officers had several problems to solve before the crossing could be safely undertaken. During flights, communication had to be maintained between the bases and the aircraft; as the position of the aircraft altered, different wave-lengths which

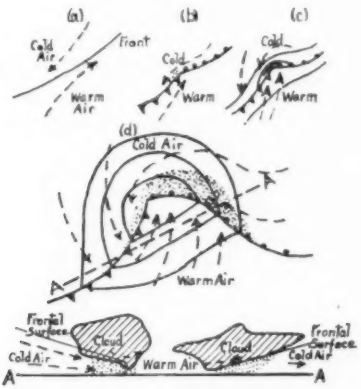
had to be determined in advance were used to maintain contact. At the same time, bearings on short or medium wave direction finders had to be given. Coupled with these was the task of maintaining, uninterrupted, the numerous meteorological schedules for which the messages constituted over 90% of the total volume of traffic handled daily.

Headed by experienced British and American experts and backed by operators with a keen interest in their job, the wireless service solved these problems so successfully that their record during the past summer is exemplary.

Delays occurred from time to time and occasionally the northern lights broke communication, but with the experience gained during the summer and additional equipment, even these few delays will in future be cut to a minimum.

VI. Meteorology

Meteorology plays an important part in the trans-atlantic flights. The route from Botwood to Foynes lies wholly within that region of the Atlantic characterized by the vigorous cyclonic storms of temperate latitudes. It is not enough for air navigation to give merely the position and relative intensities of these storm centres.



Development of a Crosssection through a Cyclone.

Fig. 4.

In the last two decades, meteorologists, led by the Norwegian school, have found that the energy of these cyclonic storms in temperate latitudes is realized from a difference in the properties (principally of temperature) of the air masses involved. In the simplest case the cyclone has a warm sector as shown in fig. 4 formed by the undercutting of the warm air by the cold. The boundaries between these masses have been termed frontal surfaces, and because of the mixing and the forced ascent of the warm air by the cold at these surfaces of discontinuity, most of the cloud and precipitation associated with the storm is localized in them. Fronts are of three main types; warm fronts where the warm air is overrunning a retreating mass of cold, cold fronts at which the cold air is encroaching on and undercutting the warm air mass, and occlusions where a warm air mass has been forced entirely aloft between two masses of cold air.

With the first of these are associated widespread cloudiness, low ceilings and light rain. These are the least dangerous in summer months. In the winter however, when the temperature of the cold air is below the freezing point, bad icing conditions may prevail in connection with them and great care has to be exercised in determining the most favourable altitude at which to fly through the front.

With cold fronts are associated thunder, lightning, hail and heavy rains. They are characterized by violent turbulence and convection throughout a limited cloud structure, with the weather usually clearing rapidly behind them. The familiar cumulonimbus cloud with its towering heads is usually to be associated with cold fronts and though their extent is small, care must be exercised in flying through them.

The occlusions can exhibit the properties of either warm or cold fronts with intensity diminishing with increasing age of the front.

The properties attributed above to these fronts are those found when there is a fairly sharp surface of discontinuity. The intensities vary greatly and at times fronts are marked by little more than a slight increase in cloudiness. In all cases, however, there is a wind shift which in extreme cases can amount to nearly 180°. It can be seen, therefore, that it is essential that the positions, intensities and structures of all fronts across the course be accurately known. The principal concern of the forecaster is to anticipate the development and motions of these fronts. Figures 5 and 6 are consecutive weather maps of the North Atlantic showing storm centres and fronts.

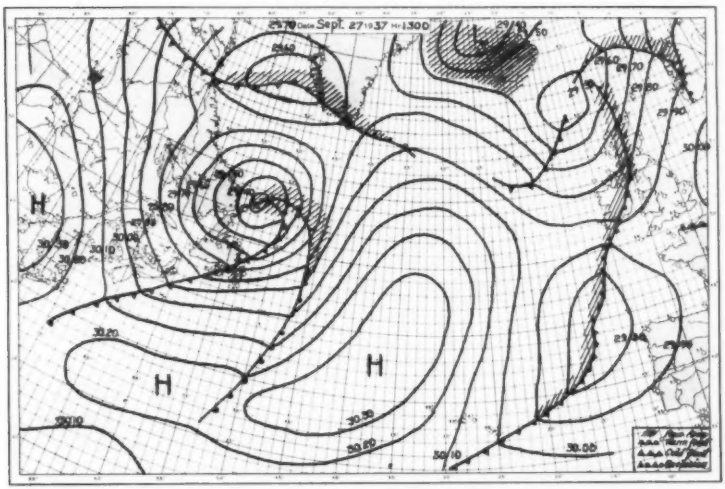


Fig. 5.—North Atlantic weather map for Sept. 27, 1937, at 13h 00m G.M.T., showing storm centres and fronts.

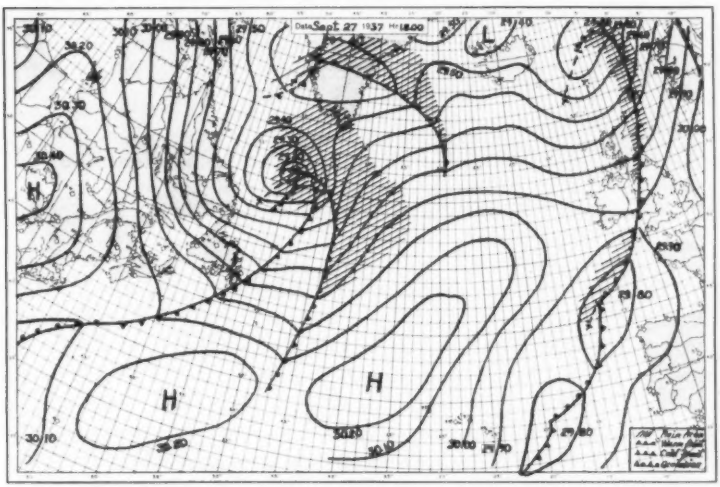


Fig. 6.—North Atlantic weather map, five hours after that in figure 5.

VII. Aims, Ambitions and Developments

The existing base at Botwood is of a temporary nature. Forty miles to the southeast on the bank of Gander Lake the Newfoundland Airport is being constructed. The position of this airport relative to Gleneagles and Botwood can be seen in fig. 1. The airport, when completed, will be one of the largest in the British Empire. The associated wireless station will be equipped with the most modern and improved apparatus and the plans for the meteorological office will make it when completed, one of the best equipped forecast centres on this side of the Atlantic.

Fig. 7.—Administration Building and part of one Runway, Newfoundland Airport.

As soon as the flying season ended with the last flight of the Cambria on September 27-28, preparation for the following summer was commenced. The meteorological offices sought ways of increasing the amount of synoptic information received and of improving the methods of exchange of analysis. The wireless offices sought ways of satisfying the insatiable desire of the meteorologists for further weather reports, and all engaged in a detailed study of the completed flights.

The establishment of an Atlantic Service is a large job and is not to be done in a year. There is much still to be done in the way of experimentation. A further season at least is necessary before even a mail service is established and there will be many months of successful mail service before a passenger service is contemplated.

Meteorological Service of Canada
Toronto, Ontario,

SCIENCE AND ETHICS*

Science, as we all know, is tested, verifiable organized knowledge; ethics is concerned with ideals, conduct and character. Any programme looking to human welfare and betterment must include both science and ethics, and there would be great gain for the world if organized religion and organized science could co-operate more effectively in the promotion of practical ethics. . . .

The ethics of great scientists is essentially similar to that taught by great religious leaders. A scientist not friendly to organized religion has said that the Decalogue of Moses might be accepted as the Decalogue of Science if the word "Truth" were substituted for the word "God". Ivan Pavlov, the great Russian physiologist, left an ethical bequest to the scientific youth of his country, which reads like the warnings of the ancient prophets. Over the tomb of Pasteur in the Pasteur Institute in Paris are inscribed these words of his: "Happy is he who carries a God within him, an ideal of beauty to which he is obedient, an ideal of art, an ideal of science, an ideal of the fatherland, an ideal of the virtues of the Gospel." John Tyndall, no friend of the church, pronounced this eulogy of Michael Faraday, one of the greatest experimental scientists who ever lived: "The fairest traits of a character, sketched by Paul, found in him perfect illustration. For he was 'blameless, vigilant, sober, of good behaviour, apt to teach, not given to filthy lucre'. I lay my poor garland on the grave of this Just and faithful Knight of God."

As scientists we are inheritors of a noble ethical tradition; we are the successors of men who loved truth and justice and their fellow-men more than fame or fortune or life itself. The profession of the scientist, like that of the educator or religious teacher, is essentially altruistic and should never be prostituted to unethical purposes. To us the inestimable privilege is given to add to the store of knowledge, to seek truth not only for truth's sake but also for humanity's sake, and to have a part in the greatest work of all time, namely, the further progress of the human race through the advancement of both science and ethics.

*From the presidential address of Edwin Grant Conklin to the American Association for the Advancement of Science, printed in *Science*, Dec. 31, 1937.

THE SMALL OBSERVATORY AND ITS DESIGN

By H. Boyd Brydon

(*Continued from February number*)

III

The designs so far presented may be considered as being about the minimum in size for a practical observatory. But the advice of the old proverb, "Don't spoil the ship for a ha'p'orth of tar", is sound in the present matter also. It may be interpreted, "Don't make your observatory too small". There is no object, for instance, in the small observatory apeing its big brother by being round or polygonal instead of rectangular. The reasons controlling the design of the great observatory do not apply to the small. The great observatory has its administration building as large or larger than itself with its offices, its laboratories, etc. In the small observatory the problem is very different. Conditions enter into its design which have little place in the other. It should be of ample size, not only because in these days, when the technical skill of the amateur telescope-builder does not fail in the production of 18-inch and even greater mirrors, the 6-inch or 8-inch of the tyro almost certainly will be superseded by a larger instrument, but also because the small astronomical observatory should be a vital force in the cultural life of the community and there should be plenty of room for visitors.

For these reasons alone the additional space in the rectangular building is too valuable to be surrendered for an incommensurable difference in first cost or an insistent feeling that an observatory should be round. Don't make your observatory too small.

The prototype of the following designs is the author's observatory (Fig. 7), built for the historic 4-inch Wray refractor acquired in 1931 from Mr. A. F. Miller, one of the Founders of this Society. It is 11 ft. by 15 ft. inside and could be larger with advantage.

To illustrate how conditions modify design, let it be assumed that the observatory is to house what we shall term a "standard" Newtonian reflector having a focal length of F8, on a German mounting, the axis of the tube being $(\frac{1}{2}\ D+8)$ inches from the polar

axis, D being the diameter of the mirror, and let the other general conditions for the design be

Length of telescope over all = 8.5 D.
Distance of diagonal mirror from lower end of telescope = 7 D.
Tube attached to declination axis at a point 2.5 D from lower end.
Minimum clearance between upper end of telescope and roof = 4 inches.
Minimum observing altitude = 20°.
Minimum distance of mirror cell from floor, 18 inches.
Width of shutter opening = $(D+16)$ inches.[4]
Gangway space, within which the minimum head room is to be 6 ft. 6 in., to be 2 ft. 9 in. wide.
Building to be rectangular.

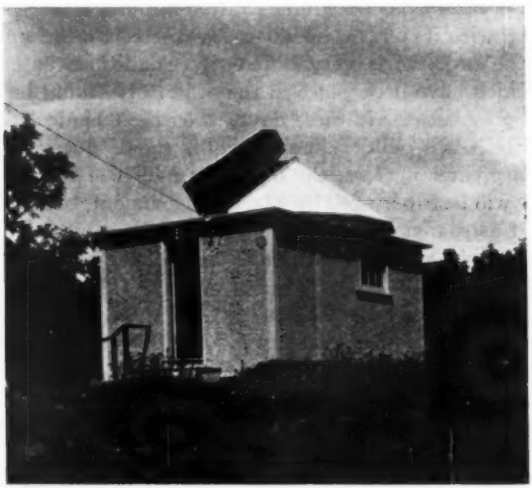
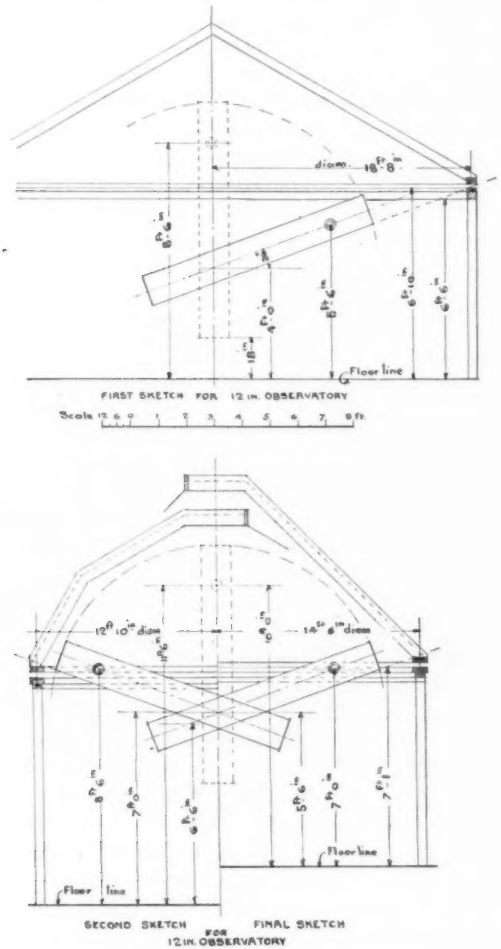


Fig. 7.—Oak Bay Observatory.

[4]A common fault in the small observatory is a too narrow opening. When working near the zenith it is a nuisance to have to swing the dome every few minutes. If a Bailey or ring type mounting be used, see this JOURNAL, vol. 30, p. 386, 1936; vol. 31, p. 16, 1937, the width can be reduced to 18 inches or 24 inches for a 12-inch or smaller instrument.

These conditions are largely arbitrary. Some must be assumed before design is possible but all can be changed to suit actual circumstances and other opinions. For instance, the head room specified is 6 ft. 6 in. Now at an altitude of 20°, one inch of head room makes



Figs. 8-10.—Sketches for 12-in observatory.

a difference of about 6 inches in the dimensions of the building, which directly affects its cost. But the smaller building involves narrower gangway space, here assumed as 2 ft. 9 in. wide. The moral is that all requirements as to space, clearances, head room, etc., must be thoroughly considered and worked out in complete detail on the drawings before construction is started. It is often forgotten that it is easier and far cheaper to change a drawing than to correct an error in the building.

I. A preliminary sketch (Fig. 8), fulfilling all the above conditions, was made for an observatory for a 12-inch telescope. From the data the intersection of the polar and declination axes is 4 feet from the floor and at minimum observing altitude, 20°, the eyepiece is about 5 ft. 6 in. from the floor. But to get the required gangway space around the elevated end of the telescope when in this position the walls must be pushed out until the diameter of the roof track is about 18 ft. 8 in.! Absurdly large for a 12-inch. The force of Dr. Campbell's remark quoted at the head of this article begins to be very apparent.

II. By raising the telescope until the intersection of the axes is 7 feet from the floor (Fig. 9), 6 ft . 6 in. of head room is obtained everywhere. The roof diameter, now fixed solely by the assumed length, F6 of the upper part of the telescope plus the clearance, becomes 12 ft. 10 in., the minimum diameter which will permit the remaining conditions to be met. The minimum eyepiece height is now increased to 8 ft. 6 in. above the floor and is about 11 ft. 6 in. high when in the zenith. As an observing stand must be used in any case, this of itself is not serious, but a single-pitched roof of the Romsey type is now impracticable and recourse must be had to a dome or a roof having a drum base with a Romsey or cone-shaped upper part, a heavy and clumsy affair.

III. Finally, as a compromise, the building shown in Fig. 10 was decided upon. The general dimensions of these three buildings are set forth in Table I. They are not final; modifications always become necessary or desirable as the design is worked out in detail.

Immediately the working drawings for an observatory are commenced the matter of shutter design becomes pressing. A small, light shutter offers no difficulty, it is simply removed from the opening and laid aside until needed again; but this becomes impracticable with any appreciable increase in size and weight. Hingeing the shutter to the side of the opening is fairly satisfactory in moderate

sizes but does not avoid the necessity of providing some means, convenient in use, by which to operate it and to hold it open against wind. Counterbalancing and mechanism of some sort are needed, so that the use of hinges, although apparently simple, is not without its problems and becomes unsuitable when the shutter is fairly large.

A shutter of the size needed in the present case is usually supported only at its upper and lower ends. It must therefore have sufficient inherent stiffness to prevent warping and sagging in service; the tracks on which it moves must be stiff enough to withstand any side-thrust by the shutter as well as to carry its weight and the whole must be supported from the structural framework of the roof. These are difficult problems to solve satisfactorily in the small observatory and various alternatives have been devised. Some of these are shown in Fig. 11.

TABLE I—PROPORTIONS OF 12-INCH OBSERVATORIES

All dimensions are in inches

	I	II	III
Diameter of roof track	224	154	174
Heights:			
Floor to top of track	82	98	85
Intersection of axes	48	84	66
Eyepiece, minimum	66	102	84
Eyepiece, maximum	102	138	120

A clever design in which the shutter is carried on a system of hinged links is due to Mr. E. H. Morse of Altadena, California. Mr. Morse has most kindly sent me a brief description and drawings of his device and photographs of his observatory[5] taken expressly for this paper, one of which, reproduced in Fig. 12 shows well the general arrangement of the shutters. The letters on the photograph refer to the same parts as on the drawings Fig. 11 B, which comprise a general section through the shutter opening and cross sections through one of the shutters in both closed and open position. Mr. Morse's description follows—

A, No. 28 galvanized iron sheathing covering dome and shutters.
B, Wooden frame members of shutter.
B_1, Flanges round edges of shutter.

[5]For a detailed description of this observatory see Barnes, "1001 Celestial Wonders", a book which merits a place in the library of every amateur astronomer.

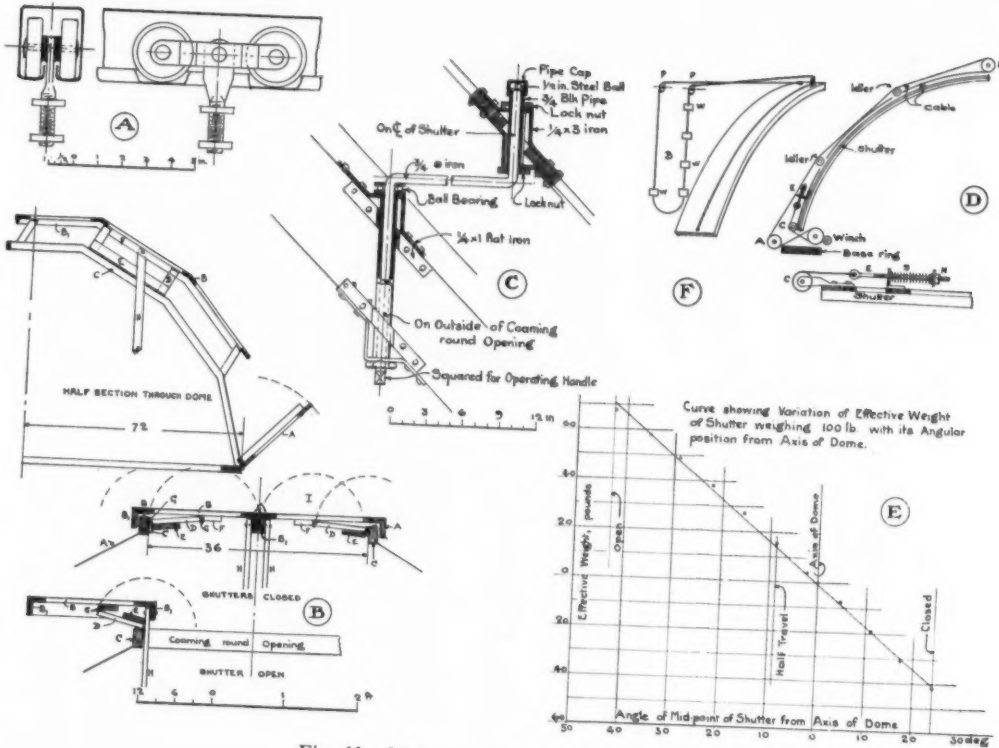


Fig. 11.—Methods of Operating Shutters.

C, Coaming round opening in dome.
D, Link to which hinges are attached.
E, Yoke joining two links to compel uniform motion.
F, Wooden block to which hinge is attached.
G, Position of hinge pins.
H, Operating handle sufficiently long to be reached from observatory floor. Secured to wall when shutter is closed to prevent wind raising shutter.
I, The other shutter similarly equipped.

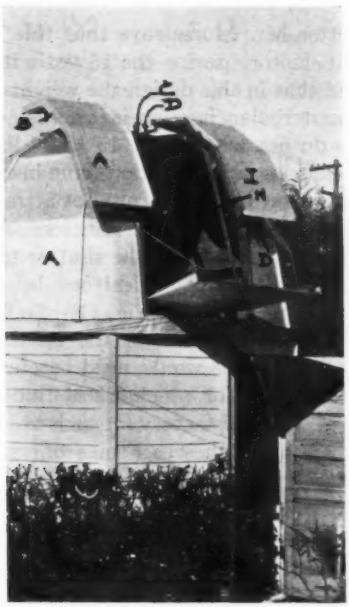


Fig. 12.—Morse's Observatory with Shutters Open.

"The shutter opening is 3 ft. wide and extends from zenith to horizon. It has a 2 x 3-in. coaming round top and sides over which the shutter flanges B_1 fit to exclude rain. The shutters consequently must be raised clear of the coaming before being moved aside. This is done by means of the links *D*, two near the centre of the

shutter which are yoked together by the piece *E* and one at each end to guide the shutter into position as it is closed.

"The shutters are made of 1 x 3-in. wood frame and sheathed with galvanized sheet iron which is bent V-shaped, see figure, at the inner edge of one shutter to cover a raised flange on the other for protection against rain.

"The handles *H*, one for each shutter, are used to open and close the shutters by hand which is done quickly and easily in one motion. The shutters are tied down against wind by hooking the handles to a swinging triangular brace fixed to inside of observatory wall."

In a recent letter Mr. Morse says that this arrangement has been uniformly satisfactory during the 15 years it has been in use.

It will be noted that in this design the weight of the shutters is not relieved by counterbalancing, nor is it necessary perhaps as the shutters probably do not weigh over 15 to 20 lb. each. Various ways of counterbalancing a link motion have been devised for use with heavier shutters but the results are not attractive as practical means of operating an observatory shutter. A method which avoids counterbalancing is to cause the shutter to move in a horizontal arc instead of a nearly vertical one by supporting it on substantial cranked hinges as at *C*, Fig. 11. So far as I am aware neither the counterbalanced link nor the cranked hinge scheme have been used. The details would need careful working out by the trial and error method for which a scale model is convenient. A scale of $1\frac{1}{3}$-in. to 1 ft. is satisfactory for such work. It is doubtful however whether either of these schemes offers any appreciable advantage over a well designed track such as that at *A*, Fig. 11, when heavy shutters must be used. This was adopted for the shutter of the Romsey roof for the 12-in. observatory discussed below.

When the shutter is curved to fit a spherical dome, these difficulties can be practically overcome by causing it to move lengthways instead of sideways as is usual. The tracks are now built directly on the two main ribs of the dome and the shutter, being supported on both sides at several points along its length, may be made much lighter without risk of sag or warping. The plan necessitates a small secondary shutter for the lower part of the opening, but this is a very simple affair, and as it aids in shutting out scattered light it is rather an advantage than otherwise.

As a shutter of this type moves from end to end of its travel, its effective weight first opposes and then aids to movement. Unless the shutter is materially heavier than that for the dome of the 12-in. observatory there is no need for counterbalancing as it can be operated successfully by a small winch mounted on the base plate of the dome as shown in Fig. 16 and in the detail drawings in Fig. 17. Such winches are not expensive and any alterations required to fit one for this use generally can be avoided by modifying the supports. However, an adequate winch can be devised without much difficulty using iron pipe for the drum and discarded automobile gears.

To insure that the shutter is under control at all times, two points require attention: (1) the weight of the shutter may be sufficient to operate the winch; (2) as the effective length of the cable will vary slightly as the shutter moves it may become slack enough to jump a pulley or slip on the drum of the winch. To prevent (1), the winch either should be worm driven or have a reliable brake. To prevent (2), first, several turns of the cable should be taken round the drum and second, the necessary tension should be maintained in the cable by the method of Fig. 11, *D*, where the ends, instead of being fastened directly to the shutter are secured to the eyebolt *E* (see the detail). Any slight variation in the length of the cable is compensated by the stout compression spring *S*, the tension being adjusted by the nut *N*. Once the tension is correctly set, readjustment will be needed seldom.

The manner of reeving the operating cable is indicated in the diagram. Starting from the eyebolt *E* the cable passes round an idler pulley at *C*, then over the surface of the shutter to and round the stationary pulley *B*, back over two idlers to the pulley *A*, then round the drum of the winch and a second idler at *C* and is finally set up taut and made fast to the eyebolt *E*.

The cable should be very flexible and preferably of phosphor bronze, having 6 strands each of 19 wires and a hemp core. Such a cable 3/16 in. in diameter is amply strong enough for the shutter here considered.

If necessary, a shutter of this type can be counterbalanced very simply. The curve, Fig. 11 *E*, shows for a shutter weighing 100 lb. how its effective weight varies as it moves from the open to the closed position. It will be noted that although the shutter moves in a circular path, if the arc through which it moves be not too

great, its effective weight varies practically uniformly in passing from the one position to the other, being in fact proportional to the sine of the angular distance of its midpoint from the axis of the dome.

The method consists in causing the shutter as it moves, to transfer weights *W*, *W* from one side to the other of the bight *B* in a line arranged as in Fig. 11 *F*. The difference between the weights on the two sides of the bight is the counterbalancing force.

The form of counterweight which best fulfils the conditions is a length of iron chain. As it has to support only its own weight, second hand chain is quite satisfactory and will probably be found to cost less in the long run than cast iron weights which may have to be cast specially and certainly will require some machining and special attachments to fit them for the job.

The least conspicuous and simplest manner of arranging such a counterpoise is to allow the chain to slide on the surface of the dome itself. An increase of 50 to 60 per cent. in the weight needed is involved due to the curved path in which the chain moves but the absence of a large external framework from which to hang the chain and its pulleys P.P., Fig. 11 *F*, is an advantage far outweighing this objection.

The space occupied by the sliding counterpoise should be enclosed by a removable cover to preserve the lubrication of the sliding surfaces from being washed off by rain or from freezing together in cold weather and to improve the appearance of the dome.

When preparing the designs for the observatory for the 12-in. Newtonian reflector it was thought desirable to check certain details "in the round" by means of a large scale model. Such changes as seemed advantageous were then made on the drawings before reproduction here. A photograph of the model appears in Fig. 13.

Although earlier in this paper objections to the dome on the score of constructional difficulty were noted, it was by no means intended to suggest that building a dome was beyond the capability of the amateur. It therefore seemed best to prepare two designs, in one, Figs. 14 and 15 a Romsey roof is used and in the other, Figs. 16 and 17 a dome.* The size of the building itself is the same in both. It has not been thought necessary to encumber the paper by repeating details common to both designs but rather to

*Blueprints of all the designs in this paper are available.

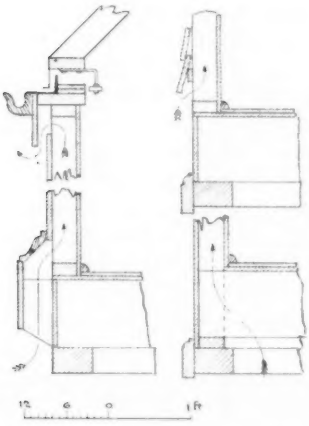


Fig. 13a.—Arrangements of Air Ducts in Walls.

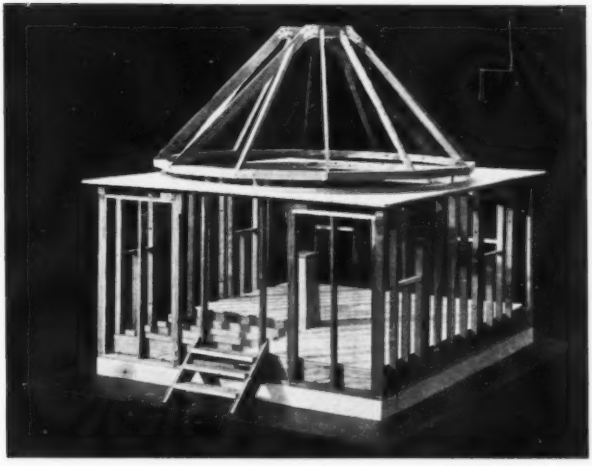


Fig. 13.—Model of Observatory for 12-in. Newtonian Reflector.

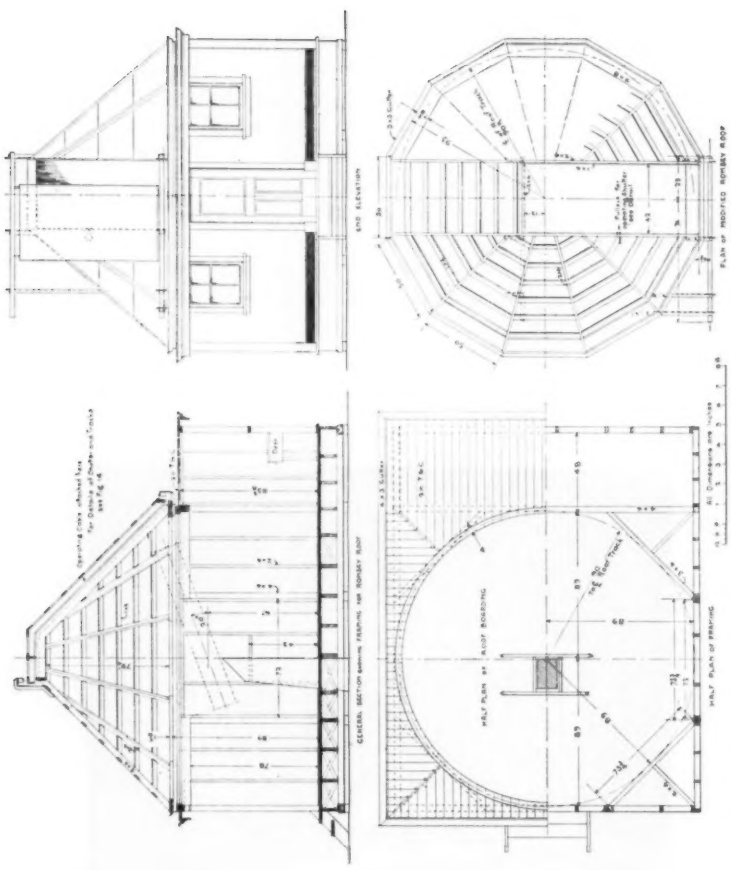


Fig. 14.—Observatory with Modified Romsey Roof for 12-in Newtonion Reflector.

show such features or differences as affect the appearance of the buildings, particularly in the method of ventilating the walls, where to reduce distortion of the mirror by changing temperature, the framing differs from the usual to permit a current of air to flow through them, entering through screened openings below and leaving at the top. A third method is seen in Fig. 13a.

Some details of the design may be discussed. The walls are in sections bolted together. The Romsey roof is in two main portions bolted to distance pieces at the shutter opening. Iron splice and corner plates are used at these connections and at certain other places where their use will improve or simplify construction. The plates, which need not be heavier than No. 12 or 14 B.W.G., add greatly to the stiffness of the framing and make for easier erection (and dismantling and re-erection).[6] The cost of the bolts and plaets is somewhat offset as much of the woodwork can be done at the mill or shop where are facilities for cheap and rapid construction. The plates serve conveniently for laying out the bolt holes on the timbers, make for accuracy and save time in erection.[7]

An appreciable saving in cost may be made by building the observatory on a 4×6-inch sill carried on and firmly bolted to wood or concrete posts instead of the concrete foundation wall shown. Concrete posts should be poured in place after the tops of the forms have been cut off to the correct height and the bolts to secure the sill set in when the concrete is poured. Wooden posts before being set in the ground should be thoroughly coated with creosote or hot tar to retard decay. This is especially necessary on the ends and for a foot or 15 inches above and below ground level. By omitting the rough floor a small further saving can be made but the result is hardly satisfactory.

The following notes on constructing the more specialized parts of the building may be useful. After the wall framing is erected and the important job done of fitting temporary braces to hold it "plumb, level and square", the diagonal beams which carry the roof track across the corners are bolted in place. The centre of the octa-

[6]By using bolts or coach screws instead of nails to secure the rafters, the main roof sections which are the only awkward pieces to transport may be reduced to their individual members which should be numbered in that case for ease in re-erection.

[7]As iron rusts quickly in some conditions, it is a good plan to dip all bolts, nuts and screws in oil or grease as they are put in place.

Fig. 14.—Observatory with Modified Romsey Roof for 12-in Newtonian Reflector.

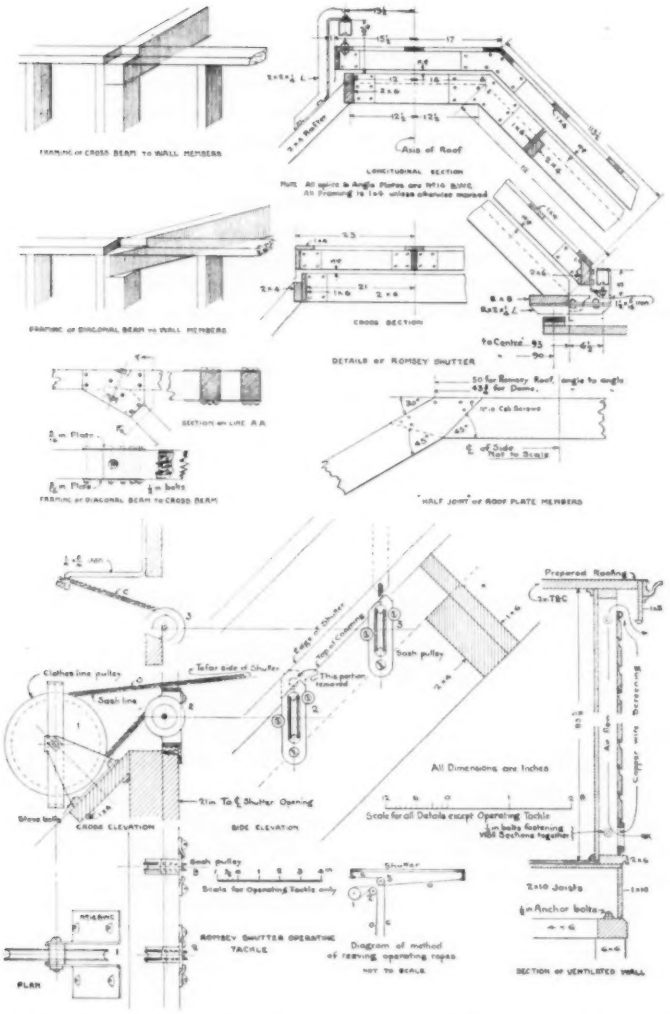

FRAMING OF CROSS BEAM TO WALL MEMBERS
LONGITUDINAL SECTION
Axis of Roof
FRAMING OF DIAGONAL BEAM TO WALL MEMBERS
CROSS SECTION
DETAILS OF ROMSEY SHUTTER
SECTION on LINE A.A.
FRAMING OF DIAGONAL BEAM to CROSS BEAM
HALF JOINT OF ROOF PLATE MEMBERS
Prepared Roofing
Clothes line pulley
Sash line
Sash pulley
Rim To ℄ Shutter Opening
CROSS ELEVATION
SIDE ELEVATION
All Dimensions are Inches
Scale for all Details except Operating Tackle
Scale for Operating Tackle only
ROMSEY SHUTTER OPERATING TACKLE
Diagram of method of reeving operating ropes
NOT TO SCALE
SECTION OF VENTILATED WALL
PLAN

Fig. 15.—Details of Observatory with Modified Romsey Roof for 12-in. Newtonian Reflector.

gon is found and marked with a nail in a plank placed across the framing for the purpose. The tongued-and-grooved boarding for the flat parts of the roof is now laid and the ends of the boards accurately cut off to a circle struck on them with the nail as centre and the same radius as the inside edge of the roof-track. The whole is given a coat of white lead in raw linseed oil, well brushed in and left to dry.

Next, the roof-track is laid. It is made in two layers of circular segments carefully cut to a sheet metal templet, the upper layer being preferably of hardwood as the wheels will run on it.[8]

The shutter for the Romsey roof is operated by two hand ropes, preferably of braided sash cord. They are rove as in the small diagram in Fig. 15. The opening rope *O*, passes round pulleys 1 and 2, the closing rope over pulley 3. In the detail drawings of the operating tackle pulley 1 is a heavy pattern of deep grooved clothes-line pulley about 5-in. diameter. To adapt it to this service the rivetted pin on which the sheave runs is knocked out and the strap removed by which normally the pulley is tied to its support. It is secured to the roof framing by two brackets of No. 14 iron, the pin being replaced by a bolt and nut, the end of the bolt set up when the nut is sufficiently tight, to prevent its backing off. Pulleys 2 and 3 are cast sash pulleys,* one end of the housing being cut away as shown. The pendant ends of the ropes inside the building should be weighted to prevent the rope from slipping or being blown off a sheave. A cleat is provided to secure the ropes when not in use.

A single shutter has been adopted in this design. If desired two can be used, changing the position of the shutter tracks correspondingly and duplicating the operating tackle. The single shutter was preferred as it avoids the centre joint, directly over the telescope mounting, which is difficult to maintain free from leakage against driving rain and drifting snow. A fairly satisfactory joint is shown in Fig. 20 *A* but whether or not a double shutter arrangement is adopted the mounting should be protected when not in use by an oil cloth or rubberized sheet thrown over it, if for no other reason than for preventing dust getting into the bearings.

Turning now to the alternative design, Figs. 16 and 17, some

[8]A $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$-inch steel angle bent to the required radius makes a fine track.

*Sash pulleys are also made of thin sheet iron stampings. They are unsuitable for shutter operation.

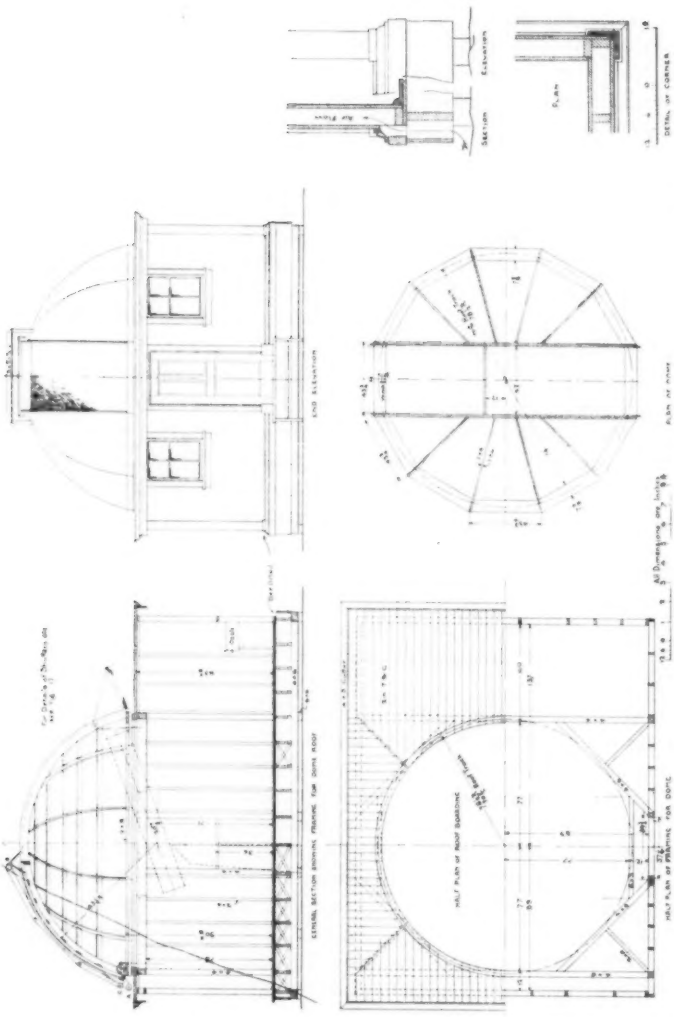


Fig. 16.—General Drawing of Observatory with Dome for 12-in. Newtonian Reflector.

notes on the construction of the dome follow. Were an observatory dome a true segment of a sphere, its design would be simple. The base plate would be circular, all ribs would be circular arcs having the same radius and a common centre and all surfaces would be spherical.

Actually this is not the case. The ribs are circular arcs but they are not necessarily struck from a common centre nor with the same radius and the surfaces between them are not spherical because, in small observatories at least, the simpler construction of a polygonal instead of a circular base is used. In this way the base plate is constructed of straight members, straight members connect similar points on adjacent ribs and the sheets of the roof covering are elliptical instead of spherical surfaces.

But when the base plate is a regular polygon, the two main ribs, those which form the sides of the shutter opening and extend from the base plate on one side to the base plate on the other, are arcs of "small" circles while the secondary ribs which spring from the angles of the base plate and are connected to the main ribs are arcs of "great" circles.

The main ribs in consequence will have a less radius than the others and the difference is increased when, as in Fig. 21, the width of the shutter opening is greater than the length of a side of the base plate.

Strictly this involves two sets of segments for the ribs, cut to different radii in order that they shall intersect correctly. On the other hand it is cheaper and quicker and more economical of material to make all the segments to one pattern. While a satisfactory compromise for the radius can be arrived at with the help of a little trigonometry it is simpler, quicker and more useful to lay out a full size drawing of the necessary parts with chalk and pencil on the floor and work from that. The kind of thing needed is shown in Fig. 17. Such a layout plus a little juggling of the centres not only shows whether a common radius can be used for all rib segments but it checks the drawings and enables all necessary measurements to be taken and all templets to be cut directly from a full size layout instead of from dimensions marked on scale drawings which may be wrong. It is an axiom in construction work to trust no dimension on any drawing including one's own until all have been thoroughly checked for correctness in all possible ways. Even then mistakes occur.

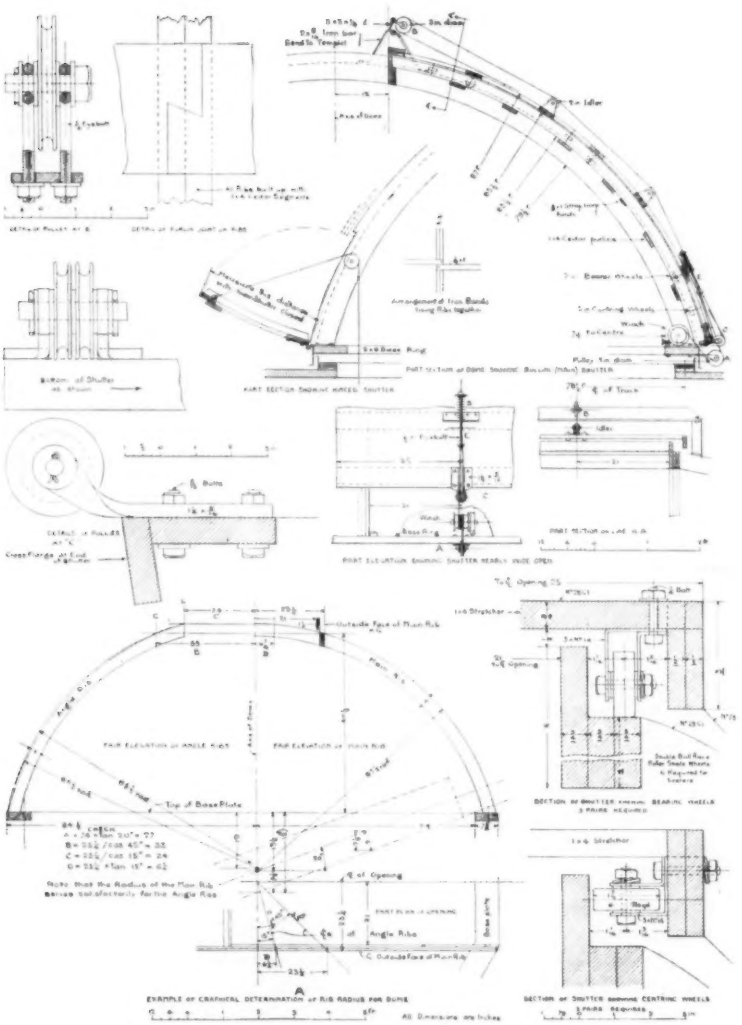


Fig. 17.—Details of Dome for 12-in. Newtonian Reflector.

In the design in Figs. 16 and 17 the base plate of the dome is a 12-sided regular polygon made of 2 x 8-in. boards put together with halved joints, see detail, at the angles. All ribs are of two thicknesses of circular segments, $\frac{3}{4}$-in. thick by 4-in. wide nett, cut to an inside radius of 79½ in. The shutter opening is protected from drifting rain by a coaming of similar segments but 6 in. instead of 4 in. wide. All radial butting joints are staggered and the segments after being painted are fastened securely together with No. 8 or 10 countersunk wood screws.

For lightness all the woodwork in the dome should be of cedar. The framing is covered with No. 28 galvanized iron secured to 1 x 4-in. purlins or stretchers spaced about 15 in. on centres. The purlins fit snugly in to notches cut their full depth in the ribs and their ends are half dovetailed together, see detail. For further security a $\frac{1}{8}$ x 1 in. strap iron band should be run from rib to rib where shown in the part section of the dome in Fig. 17. The ends extend past one another as in the detail arrangement.

The length of the hinged shutter is best determined from the position of the bottom edge of the main shutter, which when closed should overlap the hinged shutter by about 2-in. The hinged shutter is opened by a window rod hooked into a screw eye and its motion controlled by the rope shown which is used to close it.

After much experimenting in his own observatory the author has found the most satisfactory way of rotating the "dome" to be by means of a 2 x 3-in. rod permanently secured to it and traced as shown in Fig. 20 *B*. A cleat is fitted to the rod for the hand ropes for operating the shutter in the case of the Romsey and drum roofs.

When closed the shutter should be secured to the roof with at least two stout hooks on each side. At least four similar hooks should be fitted and used to fasten the rotating roof to its track when not in use. Strap iron clips or bars should be fitted also to prevent a sudden gust of wind from lifting the shutter from the roof when open. The clips should be secured to the roof boards with through bolts with large washers under the nuts as in Fig. 20 *C*, not with wood screws. Never treat wind disrespectfully.

At *D*, Fig. 20 is a view looking up at the underside of the base plate which indicates the position of the bearer wheels for the roof.

Sheet copper is the best material for covering the roof but it is expensive. Any good prepared roofing will serve for the flat parts.

Ordinary galvanized iron is quite satisfactory for the rotating roof. It will last for years if kept well painted, preferably with good aluminium paint. The standard sheet is 30×96 inches, and No. 28 gauge, weighing about $10\frac{3}{4}$ oz. per sq. ft., is heavy enough. By using templets of stout paper the sheets are easily cut to fit without avoidable waste. Roofing cement should be used in all joints and those on the rafters should be flashed.

If desired, these drawings may be used for a square building symmetrical about the intersection of the polar and declination axes by using the one half reversed for the other half, but, as has been remarked, the additional space in the oblong building will be found very useful.

If the observatory is already built square it may be enlarged very simply by using a beam to carry the roof track when the wall is removed.

First, the foundation is prepared for the wall in its new position. This done, the weight of the diagonal beams and roof-track is taken off the by wall 2×4-inch. props from the floor, bracing them together for stiffness. Next, all bolts, nails, etc., are removed from the sections of the wall to be moved and the roofing boards cut along its inside edge, care being taken not to cut into the roof-track. The wall, now free from the roof, is removed section by section, re-erected on the new foundation and braced to hold it in position. The extension sections of the side walls are set in place, checked for position and all connection bolts tightened. Next, the ends of the diagonal beams are cut to fit against the side of the new beam when in place. The beam is a 4×6-in. timber with pieces of 2×4 spiked top flush to its inside face to carry the ends of the roof boards. It is set in position and secured, and the stirrups or plates carrying the diagonal beams bolted to them. When all has been checked over, the temporary supports are knocked away and the job finished to suit the old work.

In the observatory for the 6-inch to 8-inch telescope the general problem is the same as in the larger building: to be able to reach the lowest useful observing altitude and maintain the necessary head room without excessive floor area or mounting the telescope inconveniently high.

Controlling dimensions for buildings of three sizes for a minimum altitude of 20° are shown in Table II.

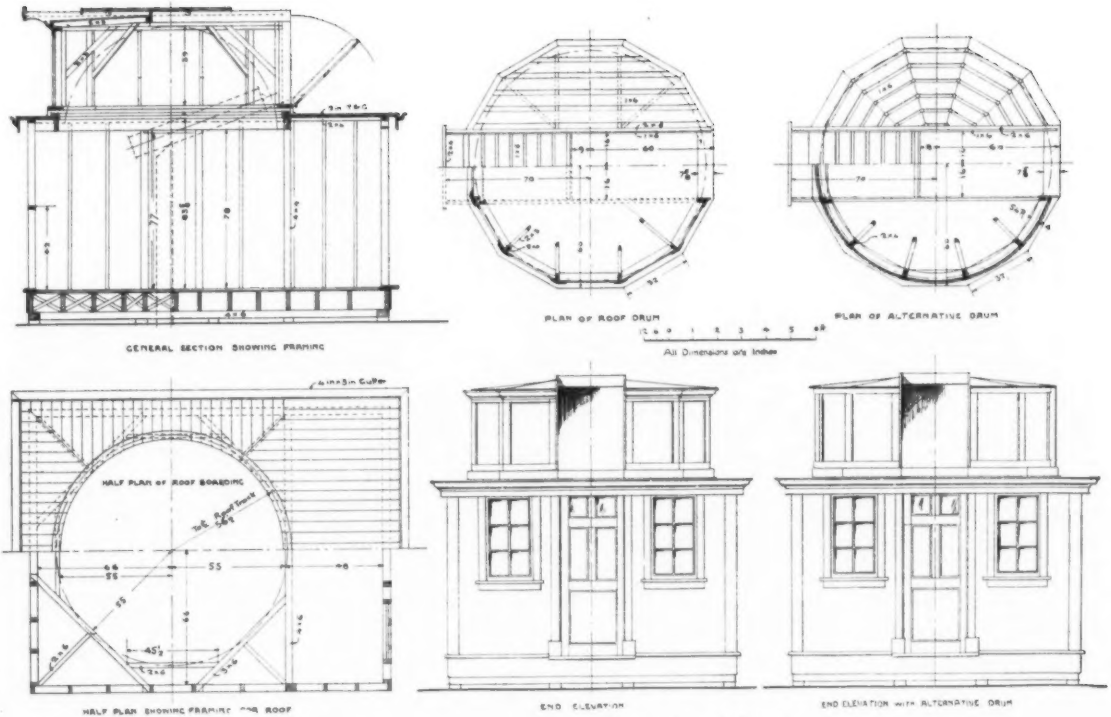

GENERAL SECTION SHOWING FRAMING
PLAN OF ROOF DRUM
PLAN OF ALTERNATIVE DRUM
All Dimensions are Inches
HALF PLAN OF ROOF BOARDING
HALF PLAN SHOWING FRAMING FOR ROOF
END ELEVATION
END ELEVATION WITH ALTERNATIVE DRUM

Fig. 18.—Observatory for 8-in. Newtonian Reflector.

The head room allowed is 6 ft. 6 in., and the height from the floor to the bottom of the shutter opening is about 7 ft. 6 in.

TABLE II—OBSERVATORIES FOR 6-INCH TO 8-INCH TELESCOPES

All dimensions are in inches

	I	II	III
Diameter of roof track	112	136	160
Height of axes intersection	69	64	60
Height of eyepiece, minimum*	81	76	72
Height of eyepiece, maximum*	105	100	96

*These are for an 8-inch telescope.

The 9-foot building, No. I, is rather small but can be used for a 6-inch telescope. It cannot be recommended, however, if only because the 6-inch most probably will be replaced by a larger instrument after a year or two.[9]

The 13-foot building, No. III, is unnecessarily large for an 8-inch but would serve possibly at the cost of a slight reduction in observable area for a 10-inch. The 11-foot building, No. II, will be found preferable for either the 6-inch or 8-inch telescope. If a 6-inch only is to be used, the building may be square but should be oblong as shown (Fig. 18) for an 8-inch or if the future use of an 8-inch is at all likely.

For the roof there is little to choose between the drum and the Romsey, either with a removable shutter as in Fig. 3, or the two-shutter arrangement of Figs. 4 or 5. In Fig. 18 the drum is used, as it has not been shown elsewhere in this article.

Two forms are shown. In the first which is polygonal in plan, some attempt at architectural treatment has been made; the second or "alternative" is a simple circular drum constructed similarly to the Hodgkinson observatory described above (p. 59), except that as the roof is practically flat instead of conical, it is carried on rafters set radially with the boards laid parallel to the edges of the base plate instead of radially as in Fig. 5.

There are two shutters. The main shutter moves lengthways on the top of the drum. The other is a small affair swinging on hinges attached to the base plate. Both are operated by ropes passing over cast sash pulleys. Some details of the drums are shown to a larger scale in Fig. 19. The bearing and centring

[9]A Table showing the relative performance of telescopes with increasing aperture is given in the Appendix.

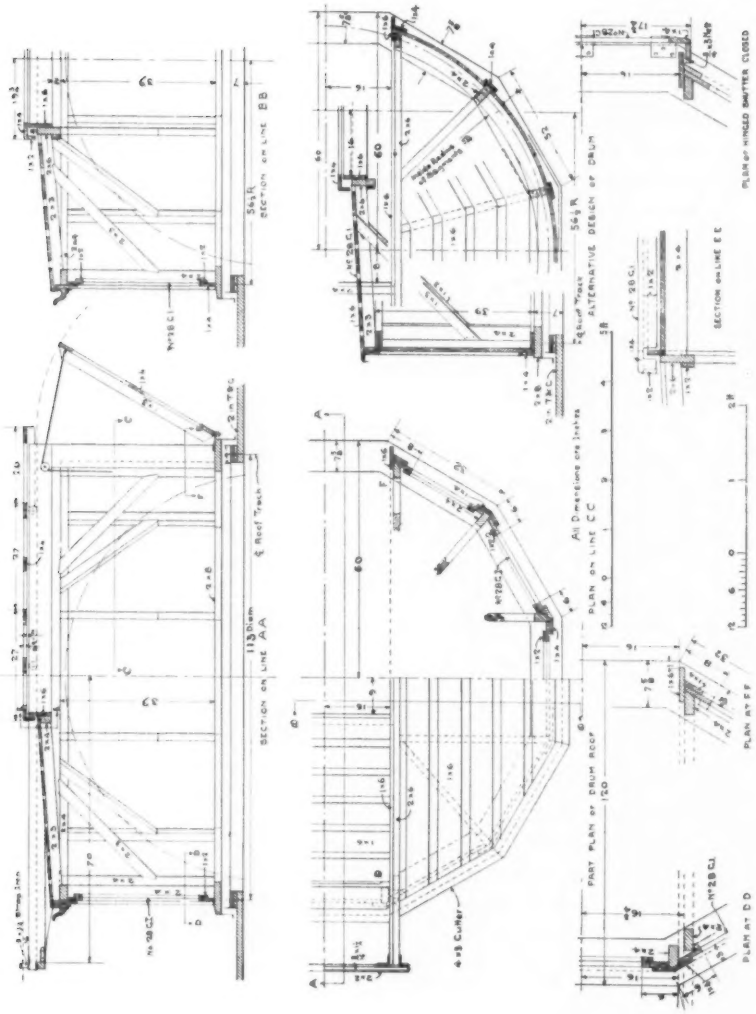


Fig. 19.—Details of Drums for 8-in. Observatory.

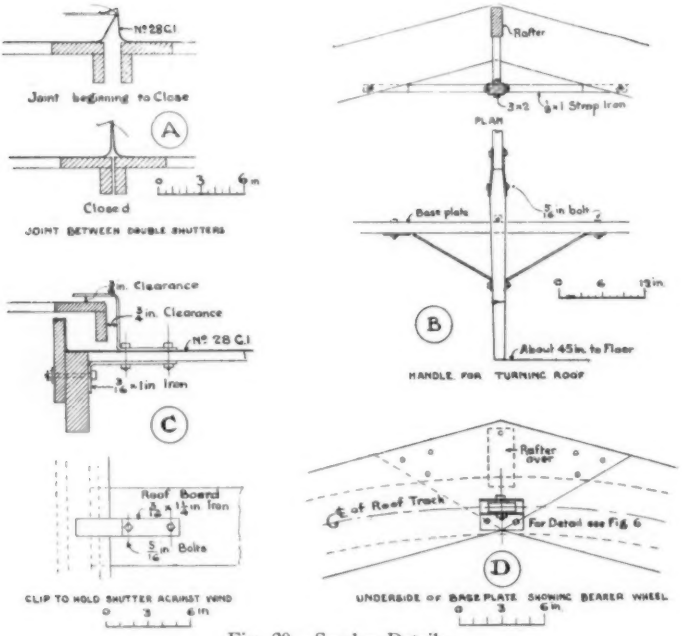


Fig. 20.—Sundry Details.

wheels for the main shutter, two pairs of each, are ball bearing skate wheels mounted as in Fig. 17.

In the alternative design galvanized iron can be used instead of wood for sheathing the drum, lapping the sheets on the uprights where the joints will be covered by the 1 x 4-in. pilasters. If this is done it would be well to provide supports for the sheets by adding a ring of segments midway between the top and bottom rings. The ring would not be continuous but would consist of separate segments having the same radius as the top and bottom rings, nicely fitted between the uprights and toe-nailed securely to them. Some reduction in weight would result from this substitution.

The flat portions of the roof can be covered with prepared roofing of "Duroid" or equal quality but galvanized iron should be used for covering the drum and the shutters as it adds to the rigidity of these moving parts.

(To be concluded)

THE ROTATION EFFECT IN ECLIPSING BINARIES AND STELLAR DIMENSIONS

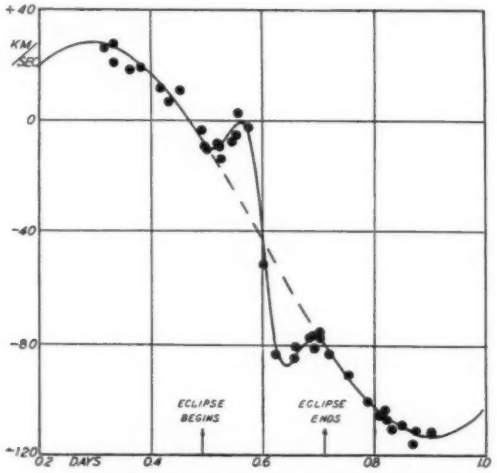
By R. M. Petrie

AMONG the many stellar systems comprising two stars in revolution about their common centre of gravity, there are a few whose orbital planes pass close to the solar system. They are known as eclipsing variables or, more suitably, as eclipsing binaries. In most cases the system consists of a smaller, hot and bright star and a larger (in volume), cooler and fainter companion. In every revolution we observe, therefore, a weakening and subsequent strengthening in the light of the system as the fainter star passes in front of, and partially or completely eclipses, the brighter star. Eclipses of the fainter object, one-half period from those of the brighter, are sometimes observed as small variations in the light curve. The light variations of the well-known eclipsing binary Algol illustrate these effects admirably.

When we make spectroscopic observations of eclipsing binaries we may measure the varying line-of-sight (radial) velocities and secure the orbital elements as we do with ordinary spectroscopic binary stars. Observations of radial velocity in eclipsing stars, however, disclose a peculiar and interesting effect. This is illustrated in Figure 1 from observations of the eclipsing binary RZ Cassiopeiae made by J. A. Pearce. Soon after the eclipse begins the observed velocities deviate markedly from those to be expected from usual orbital motion. Before mid-eclipse the velocities are too positive (*i.e.* they indicate a motion of recession); the effect disappears at mid-eclipse and is reversed thereafter. The explanation of this curious result lies in the fact that the star being eclipsed is rotating on an axis, in the same direction as its revolution about the barycentre of the system, with its axis of rotation perpendicular to the orbital plane. Before mid-eclipse, then, the receding hemisphere of the bright component is uncovered whereas the approaching hemisphere is partially eclipsed by the fainter companion. There is, therefore, an excess of rotational motion of recession over that of approach, which appears, in radial velocity observations, as a positive deviation from elliptical orbital motion. At mid-eclipse the rotational motions of approach and recession cancel one another, owing to the symmetry of that position; after

mid-eclipse there is an excess of rotational motion of approach, hence the measured velocities are more negative than pure orbital motion would predict and they fall below the curve.

The interest and importance of this "rotation effect" lie in the result that, upon certain assumptions, we may from it secure the size of the star being eclipsed. Having this dimension we may then, by combining photometric and spectroscopic data, secure the masses and densities of the stars and the absolute dimensions of the



ROTATION-EFFECT UPON RADIAL VELOCITIES IN RZ CASSIOPIAE

Fig. 1.

system. These data are of great importance since they are available for only a very few stars and are necessary to our understanding of stellar structure and evolution. In the case of an eclipsing binary showing only one spectrum an investigation of the rotation effect is, at present, the only means of securing the dimensions.

The rotational deviation from orbital motion gives us the equatorial velocity of rotation of the eclipsed star and finally its size, but in this study we require the calculation of a quantity called the "rotation-factor". This is a mean value of the rotational velocity, in the line of sight, in terms of the equatorial velocity,

averaged over that part of the disk visible at the particular phase of observation. This factor when divided into the observed velocity deviation then gives (by its definition) the desired equatorial velocity of rotation of the star being eclipsed. The calculation of the factor has been made previously[1, 2] by a graphical method which is laborious and time-consuming, especially if many observations are to be treated. In order to avoid these graphical computations the writer has derived formulae which allow one to compute the rotation factors for any phase during eclipse when the usual photometric elements are known. The resulting formulae are somewhat involved but offer no difficulty to the computer, and indeed most of the work may be performed upon the slide-rule. The derivation of these formulae will not be given here since they require numerous technical operations not envisaged in the scope of this note and are better described separately.[3] The method employed may be described however. We wish to secure a mean value of the rotational velocity averaged over the fraction of the disk which is uneclipsed. Now the observed radial velocity of a point upon a projected stellar disk can be shown to be proportional to that point's distance from the projected axis of rotation. If we therefore divide the visible portion of the disk into a multitude of small areas and multiply each one by its distance from the rotation-axis, then the sum of all these elements divided by the total area visible gives the desired factor. Mathematically the problem is an application of the mean-value theorem and is related to the problem of finding the centre of gravity of plane figure of uniform thickness and density.

Several cases arise in the treatment and formulae have been developed for each case. Spherical stars with the eclipsing body larger than the eclipsed star and systems in which the eclipsing body is the smaller, have been studied as well as ellipsoidal stars. The formulae have been derived without the use of limb darkening since that effect is uncertain at present in early-type stars, and since its inclusion leads to rather complicated relations.

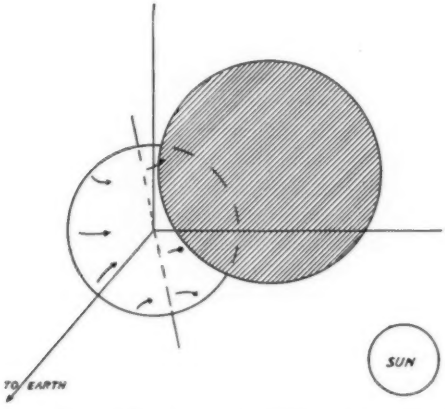
As an example of the use of the rotation-effect let us consider an observation of RZ Cassiopeiae, an eclipsing system showing only one spectrum. An observation made approximately one and

[1] D. B. McLaughlin, *P. O. Univ. Mich.* Vol. 6, No. 4, 1934.

[2] R.A Rossiter, *Ap. J.*, Vol. 60, p. 20, 1924.

[3] To appear in the Publications of the Dominion Astrophysical Observatory.

one-half hours after mid-eclipse shows a deviation from the orbital radial-velocity curve of -19.7 km/sec. The situation is shown diagrammatically in Figure 2, from which one can see that an excess of motion of approach from the uneclipsed portion will be observed. The rotation factor for this phase is found to be $F \sin i + -0.187$ and hence the equatorial velocity of rotation of the bright star is $19.7/.187 = 105$ km/sec. If we now make the usual assumption that the orbital period coincides with that of rotation then the radius of the bright star (the period is 1.19525 days) is $r^b = 1{,}730{,}680$ km. and from the photometric data the



A CONFIGURATION OF RZ CASSIOPEIAE DURING ECLIPSE

Fig. 2.

ratio of sizes is $k = 0.768$, hence the radius of the fainter component is $r^f = 2{,}251{,}000$ km. Now from the photometric data we know the radius of the brighter star in terms of the radius of the relative orbit (*i.e.*, the sum of the orbital radii of the components) while the spectroscopic orbit supplies the radius of the orbit of the brighter star. From these data we may secure the ratio of the masses of the bodies and finally the masses themselves. In this example the orbital radii turn out to be 1,172,000 km. and 6,485,000 km. for brighter and darker components, respectively, while the masses are 10.3 and 1.9 times that of the sun. The mean densities may now be secured since we know the masses and radii and the

densities are found to be 0.94 of water for the brighter star and 0.08 of water for the fainter.

We see then that the observation of the rotation-effect in eclipsing binaries and a knowledge of rotation-factors lead us to extensive information regarding the physical properties of these systems. In this example we have the picture of two suns, approximately three and four times the size of our luminary, revolving about their common centre of gravity in about one and one-quarter days at a distance about twenty times that from the earth to the moon. The principal star is about the density of water and ten times the mass of the sun while the other is more rarefied and has twice the solar mass. A diagrammatic representation of the system corresponding to the observation discussed above is given in Figure 2.

The writer wishes to thank Dr. J. A. Pearce of this observatory for his kindness in making available his results on RZ Cassiopeiae, in advance of publication.

Dominion Astrophysical Observatory,
Victoria, B.C.
March, 1938.

A NEW THEORY OF THE EARTH'S CORE

By Joseph Lynch*

THE nature of the earth's interior has long been a puzzle. How hot is it? At what pressure is its centre? Is it solid or liquid? Its density as a whole seems to have been well established by Boys and others to be about 5.5. Good figures for the crustal density seem to be about 2.7. We are thus forced to the conclusion that the density increases with depth. Jeffreys postulates 12 for the core-density.

That a core exists is proved quite conclusively by seismology. Reflections from and refractions at a discontinuity about half-way towards the centre of the earth seem quite well established. The velocity of earthquake-waves, both compressional and shear, seems to increase steadily and sharply down to the core whence the velocity becomes more or less constant until the waves emerge from the other side.

Beginning then half-way down in the earth we have this comparatively dense core, but is it solid, liquid, or gas? How rigid is it? Tidal phenomena, the Eulerian period, and seismic phenomena all postulate a core less rigid than the crust. For perfect rigidity an Eulerian period of about 306 days would be required. For zero-rigidity a period of infinity would be needed, whereas the period observed from changes of latitude is 427 days. To comply with the data of tidal phenomena and the Eulerian period a liquid core was suggested and is still quite generally held outside of seismological circles. In the shear-wave of earthquakes, seismology offered a tool with which the rigidity of the earth could be readily probed. At first it seemed that the shear-wave did not penetrate the core and this was taken to confirm the view already held that the core possessed zero-rigidity or was a fluid. However, four or five seismic investigators in various countries, after careful independent study of different quakes, have come to the conclusion that the shear-wave does pass through the core. Hence it seems that we are faced with the alternatives: (1) The core is a liquid, but a liquid under conditions existing at the centre of the earth can transmit a shear-wave; (2) the core is a solid, but a solid of much less rigidity than the crust. The

*In the Transactions of the American Geophysical Union, 1937.

present paper dares to add a third possibility, that the core is neither liquid nor solid, but a solid solution—a metal heavily occluded with a gas. Perhaps the suggestion is fantastic, but it was considered sufficiently worth while to determine what effect, if any, such an occluded gas would have on the rigidity of a metal. Palladium was selected as the metal because of the ease with which it could be occluded with hydrogen. A torsion-pendulum, consisting of a half-millimetre palladium wire as suspension and a small magnetized steel needle as the mass, was set up in an alternating-current field. The period was found by resonance, which was found to be extremely sharp. The results show a very definite effect produced on the rigidity of the palladium, a decrease varying from one-tenth to one-fifth of the coefficient of rigidity. The variation in length of the pendulum amounted to about 1 cm. in a 7-cm. length of wire. The results have been quite erratic but always showing a decrease in rigidity. The experiment is being continued with the hope of obtaining a curve showing the relation between change of rigidity and amount of gas occluded.

It must be emphasized that no attempt has as yet been made to look for and answer the possible objections to such a metallic sponge for the earth's core, but it was deemed worth while to look into the effect of occlusion on the elastic properties of a metal and the purpose of this paper was simply to state that apparently the coefficient of rigidity of palladium is reduced by an amount of the order of one-tenth or two-tenths when occluded with hydrogen up to several hundred times its volume. Further results will be published later.

Fordham University,
New York, N.Y.

REVIEW OF PUBLICATIONS

The Pageant of the Heavens, by Frederick Warren Grover, Ph.D. Pp. xix+157, $7\frac{3}{4}$ x $10\frac{3}{5}$ ins. New York, Longmans, Green and Co., 1937. $3.50

This volume adds another to the already long list of popular works on astronomy, but it is an unusual and distinctive book even at first glance. The chief aim of the book appears to be to impress the reader with the beauties of the heavens, at the same time instructing him in the scientific background. Small stars are dotted in artistic groupings as headings, and many suitable poetic quotations are included. The book is intended to serve as an introduction to general astronomy for the interested layman or beginner. An unusual feature is that it contains no pictures.

The author is a professor in Union College, and the information contained in the book is of course sound. A novel feature is a very long table of contents which serves as a good outline for the material. The volume is in three parts. Part I deals with the practical identification of the constellations and brighter stars, with descriptions of the sky at all seasons. Eight good maps of the entire sky, with white stars on a black background, are to be found in a pocket built into the back of the book. The appendix contains a helpful list of pronunciations of star and constellation names.

Part II of the book gives an account of the solar system, while Part III describes the starry universe. This third section does not go into as much detail as one could wish, since only sixteen pages are devoted to stars, and only one page to the very important subject of nebulae.

The appendix contains a list of titles for further study; while all of these are sound astronomical works, in some cases the books listed have been generally supplanted by more up-to-date works.

To those who would learn to know and love the sky the book should be a help.

H. S. H.

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

Summer Meteor Observations

As I have frequently mentioned in these pages the summer is an excellent time to start meteor observing since warm weather coincides with the year's richest meteor shower, the Perseids. All those who hope to have time to observe meteors during July and August, either visually, photographically, or with instrumental aid, should communicate immediately with the writer at the Dunlap Observatory, Richmond Hill, Ont. Charts and instructions are available for those who have serious intentions of observing, even if it is only for a brief period. Every additional observation helps in this field.

The maximum night for the Perseid shower will probably be that of Aug. 12-13. Unfortunately the moon is only two days past the full on this date and in Aquarius, just under 80 degrees from the radiant. This means that the faint meteors will be missed by the visual observers and that photographic exposures will have to be much shorter than usual. A special photographic programme will be carried out at the Dunlap Observatory on the three nights Aug. 11-14 and meteor observations of any kind made in other parts of Ontario at this time will be particularly valuable. Plots of the shape and the drift of long enduring fireball trains are especially desired.

Apart from the few nights near the Perseid maximum the whole first half of August and the last week of July are rich in both sporadic and shower meteors and are excellent times to gain good experience in conducting programmes of meteor observation. Since New Moon is on the evening of July 26, this week will, in many ways, be more favourable for meteor observation than later on when the moon is so bright. The Delta Aquarids, a fairly good shower some years, have a maximum on July 28. It is hoped that the interest in meteor photography which was productive of such valuable results last August, will be even greater this year.

Two Bright Fireballs

Reports of two bright fireballs, seen during April, have been received recently. The first was observed by Mr. J. W. Such from

a point just west of Belleville, Ont., at 7.30 p.m. on April 12, 1938. It was observed over its entire path and described as extremely brilliant in spite of a nearly full moon not far away. It passed horizontally across the southern sky from east to west, remaining visible for about 5 seconds and during this time changing in colour from reddish to a blinding white and back to red again.

The second fireball was observed from near Toronto at 8.52 p.m. on April 16. It moved slowly from Arcturus to Corona and was white and of magnitude −4. The writer would be glad to receive any additional reports of these brilliant meteors.

Telescopic Meteor Observations—Autumn, 1937

The following telescopic meteor observations were made by Mr. Jack Grant at Orillia in continuation of the programme reported in the Journal for Oct. 1937. The instrument used was a prism binocular, aperture 1.2 inches, field 6.9°, magnification 8x, efficiency 42 on the arbitrary scale previously described. The magnitudes given in the last column have been corrected for the light gathering power of the instrument.

Date	E.S.T.	Weather factor	Region	Total minutes observed	Meteors	Mags.
Oct. 2- 3	10.08-10.45	10	ζ Aur.	34	0	
" 8- 9	11.24- 1.27	7	8° N. of zenith	78	1?	7
" 9-10	10.30- 1.14	8	η Ari.	40	4	9, 5, 5, 7
" 10-11	11.30- 1.19	10	zenith	59	1	7.5

P. M. M.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Tree Planting at the David Dunlap Observatory.

On the afternoon of Tuesday, April 25th, four oak trees were planted in front of the David Dunlap Observatory. This forms an auspicious start to the eventual landscaping and reforestating of the large observatory grounds. The ceremony was private and informal. The trees were planted by Mrs. Jessie Donalda Dunlap, the donor of the Observatory, Sir William Mulock, Mr. Moffat Dunlap and Professor Chant, assisted in each case by Mrs. Dunlap's little granddaughter, Donalda. For years Sir William has been widely known for his active interest in trees, while the many astronomers who were privileged to visit Mrs. Dunlap's farm a few years ago will remember its beautiful landscaping.

In the observatory library Mrs. Dunlap was hostess at tea to those who planted trees, and to Mrs. Chant, Mrs. Moffat Dunlap, and the observatory staff. President and Mrs. Cody were unfortunately not able to be present. F.S.H.

Notes from the Dominion Astrophysical Observatory Victoria, B.C.

In continuation of the observing statistics from the September, 1937, issue of the Journal, we have the following data from the records of the observatory.

			19-year average	
1937	Nights	Hours	Nights	Hours
June	15	71	17	84
July	19	101	23	128
August	18	130	24	150
September	21	147	20	152
October	17	117	17	129
November	14	69	12	85
December	7	48	10	64
1938				
January	11	50	10	68
February	11	75	13	92
March	19	121	16	96

The ten months here recorded show that the observing weather has been about ten per cent. poorer than the average for the corresponding months since the observatory was opened. All but the month just closed have been poorer; it is hoped the tide has turned.

Approximately 23,166 persons visited the observatory during these ten months and it would appear that there is a gradual increase in the number of our visitors although we have not had many astronomers recently.

The staff members are frequently called upon for outside addresses to church clubs, service organizations and Canadian clubs. During the ten months under consideration Dr. Beals has given 1, Dr. Petrie 4, Dr. McKellar 4, Dr. Pearce 7 and the writer 7 addresses. Dr. Petrie and the writer lectured before Vancouver organizations, while Dr. Pearce made a tour of up-Island Canadian clubs. In addition, a half-hour coast-to-coast broadcast describing the activities of the observatory was staged on January 10 and favourable comments have come to hand from several centres in eastern Canada.

The usual grist of papers describing recent researches at the observatory were presented at the Christmas meetings, a total of seven being sent to the Bloomington and Indianapolis gatherings. Several are being prepared for the June meeting of the A.A.A.S. which is to be held in Ottawa.

Numbers 20, 21 and 22 of Volume VI of this observatory's Publications were recently put through the press and distributed. The first mentioned is the joint investigation on Nova Lacertae; the other two are orbits by Drs. Petrie and McKellar. This completed Volume VI and the index has been issued. Numbers 1 and 2 of Volume VII have been printed but not distributed. The first one lists the radial velocities of 917 Class A stars, by the writer; the second is a binary orbit by the writer and Mr. Blanchet.

Improvements to the equipment are always taking place. The visual eye-piece for the 72-inch telescope used for Saturday night visitors has been reconstructed and definitely improved. A second plane grating, ruled by R. W. Wood, on an aluminized base and giving a very bright second order in the visual region has been secured and used with considerable success. A photometer for use with the 72-inch is about completed. Apparatus for aluminizing our secondary mirrors has been built up locally under the direction

of Dr. McKellar, and both secondary mirrors have been successfully aluminized with consequent improvement to the spectra secured.

Dr. Andrew McKellar was married on March 26 to Miss Mary Crouch of Saanich and they are at present on a honeymoon trip to southern California. Mr. Kenneth Wright also was married September 25 of last year to Miss Margaret L. Sharp of Ottawa. The staff members in both instances, made suitable presentations of silver accompanied by their congratulations and best wishes.

W. E. H.

Apply Heat, Get Cold!

In the "gas" refrigerator seen in the modern household one ignites a small jet of illuminating gas and obtains the cooling of the food in the cabinet. Also, for many years the compressors of ice-making machines have been driven by steam engines which develop their power when fuel is fed to their fire-boxes. These things are familiar to us; but it comes as a surprise when it is stated that the immense accumulations of ice which existed at various parts of the earth some thousands of years ago were probably produced by an increase in the radiation from the sun. Yet that such could have been the case was cleverly demonstrated in a lecture before the Royal Institution in London by Sir George Simpson, the head of the meterological service in Great Britain. The lecture was printed in *Nature* of April 2, 1938.

It was formerly thought that aeons ago the earth was intensely hot, that it has been cooling ever since and that when the terrestrial heat is exhausted our end will be like the frigid lifeless moon. However, the geologists discovered indubitable evidence that certain portions of the earth's surface have at one time been covered with thick ice and some thousands of years later with lush tropical forests. The cause of these great climatic changes has for a long time been an outstanding problem of interest to geologists, astronomers and physicists and many theories have been propounded. It is becoming more and more accepted that no alteration in the earth itself can account for the sequence of changes in its climate as shown by the latest ice ages—that these must have been due to influences outside the earth. Naturally we turn to the sun. Sir George Simpson discussed the effect on the earth's climate if the sun's radiation should pass through cycles of increase and decrease. He showed that the results would

be very similar to those observed by geologists. He showed that a glacial epoch would be produced as the sun's radiation increased and another when it decreased and that the interglacial periods would be very similar to those observed in the Alps by Penck and Brückner.

He illustrated his views by a very neat experiment. Into a cylindrical glass vessel, perhaps four inches in diameter and twenty inches high, was poured a shallow layer of water, and on the top of the vessel was a metal cover from the lower surface of which projected downwards in the glass vessel some metallic rods. Upon the cover was placed solid carbon dioxide which gave a low temperature to the metal rods at the top of the vessel. The water at the bottom represented the equator of the earth; the very cold metal at the top, the earth's polar regions. When the water was at room temperature vapour rose from it and was condensed, appearing as ice on the metal at the top. When the water was cooled by dropping ice into it there was less evaporation and less ice deposited at the top. As the water was heated from underneath the evaporation was greater and the accumulation of ice at the top was greater, *i.e.*, by adding heat there was an increase of ice. When the temperature of the water rose above a certain point, however, the ice began to melt and the accumulation on the metal top disappeared. The results of the experiment were an impressive demonstration of the possible correctness of his theory.

That the sun is a variable star with a very long period is a not unreasonable hypothesis, although there are no astronomical observations to support it. The results deducible from it seem to explain the observed facts better than does any other theory.

An Attractive Publication

The various publications issued by the numerous astronomical organizations effectively assist the cause to which each is devoted, some in a very modest way, others more pretentiously. Generally they are the outcome of unselfish enthusiasm of persons who never expect (or receive) any monetary return for their labours. One of the most attractive of these periodicals is *The Sky—Magazine of Cosmic News* which is published monthly as the bulletin of the Hayden Planetarium, New York City. Among the contents of the May issue are: The skyward look, The story of the stars,

Is it a meteorite?, Practical advice in telescope making, Two eclipses in May, Observing lunar eclipse, Astronomical societies, New methods may find million-ton meteorite, Books and the sky, Astronomy is fun, Planetarium news. The editor is Dr. Clyde Fisher, the director of the Planetarium, and the illustrations are numerous, striking and beautiful. One would expect the hosts of visitors to the Planetarium to carry away copies of the magazine as mementos of the great institution. In the same number is also a pleasing portrait of Charles Hayden whose name the institution bears and who bequeathed his large fortune to public purposes.

In the two articles on the "million-ton meteor" is an account of the latest attempts to locate the meteorite body (or bodies) at the well-known crater in Arizona. The latest geophysical methods have been used to locate any iron which may be below the surface, but the indications are not very certain or promising. The whole story is very interesting.

C. A. C.

MEETINGS OF THE SOCIETY

AT VANCOUVER

March 8, 1938.—The 54th regular meeting of the Vancouver Centre was held in Room 200, Science Building, University of British Columbia, at 8.00 p.m. on Tuesday, March 8, 1938.

Mr. Seto More then gave a summary of our present knowledge of the planet Mars, dealing chiefly with its physical features and the various opinions that have been expressed regarding the nature and origin of its surface markings. The successful use of colour-filters in the obtaining of better photographs of Mars was discussed. The speaker concluded by describing the behaviour of Mars' two satellites, Phobos and Deimos.

The main lecture of the evening, "The Origin of the Solar System", was given by Dr. R. M. Petrie, of the staff of the Dominion Astrophysical Observatory at Victoria.

An account of some of the early unsatisfactory theories served as an introduction. The possibility of the separate capture of planets by our sun was discussed, and the following four very good reasons for the rejection of this theory were presented: (1) The comparative isolation of the solar system in space; (2) the small probability $(\frac{1}{2})^{199}$ that the capture method would result in such a system so nearly in one plane; (3) the similarity in the rotations of the planets; (4) and the similarity in their orbits. The alternative is the theory of the simultaneous origin of the planets from solar material.

The two widely accepted alternative hypotheses, the nebular hypothesis of LaPlace, and the more modern planetesimal hypothesis of Moulton and Chamberlain were described and explained in considerable detail. For several reasons, the former theory has been almost entirely discarded. Two sufficient reasons involve considerations of the stability of the rings of Saturn, and the application (to the matter in the solar system) of the law of the conservation of angular momentum.

In dealing with the modern theory, Dr. Petrie discussed the probable time and nature of the postulated stellar encounter (as suggested by Jeans), the probable age of the earth, the difficulty of explaining planetary rotations, and the recent suggestions by Russell for modifications of the theory.

Lantern slides illustrating many of the points of the lecture were then shown.

H. W. FOWLER, *Secretary.*

The Royal Astronomical Society of Canada

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